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UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

THOUSANDS KILLED BY COAL-MINE EXPLOSIONS IN THE UNITED STATES

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D. HARRINGTON, J. J. FORBES, AND W. J. FENE

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

THOUSANDS KILLED BY COAL-MINE EXPLOSIONS IN THE UNITED STATES[1]

By D. Harrington,[2] J. J. Forbes,[3] and W. J. Fene[4]

INTRODUCTION

Seldom, if ever, has any mining hazard presented itself that some method has not been devised to control it to some extent; the degree of success of such control depends largely upon the intensity of desire to prevent suffering, injury, and death. The economic saving to be realized - and the more definitely this is realized by all concerned, the more quickly and effectively will the hazards be handled - is an important incentive to prevention of accidents. Preventing coal-mine explosions is by no means a complex problem; all that is necessary is sensible, conscientious, sustained effort. The fact that explosions can be prevented has been well-demonstrated by the record of the past few years; the average annual death toll from explosions for the 5 years 1906-1910 was 438, and for the 20 years prior to 1929 it was 265; during the past 4 years an average of only 32 deaths per year resulted from this cause, although the annual production during that time varied but slightly from that of 1906-10. This is a truly remarkable reduction, and if other types of mine accidents had been reduced in the same ratio only about 300 would be killed annually in our mines instead of the nearly 1,300 killed in 1936 and the approximately 2,000 killed annually for many years.

Although frequency of occurrence of explosions has not lessened greatly during the last decade, their severity decreased markedly, which would indicate that effective means are being taken to prevent the spread of explosions, even though ignitions and their causes are not being handled nearly as effectively as they might or should be handled. Several large coal-producing States, which in the past have experienced numerous disastrous explosions, have been free from such disasters for continuous periods as long as 8 years in the relatively recent past. The application of rock dust to underground surfaces has been an important factor in preventing widespread explosions; some of the most dangerous mines have been rock-dusted fairly adequately, and this has been amply repaid in the reduced severity of explosions, as heretofore indicated; however, many have applied rock dust apparently without giving much consideration to the amount required to prevent

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propagation of flame; such ineffective methods may give a false feeling of security and it would be well for our coal-mining people to give this matter due thought with subsequent adequate action.

The purpose of this circular is to summarize data on explosions in the various States published by the Bureau of Mines5/ or contained in its files.

SUMMARY OF MINE EXPLOSIONS, BY STATES

Table 1 gives available data on explosions in the coal mines of the United States (bituminous and anthracite), in which one or more persons were killed. The records of these explosions have been compiled from files of the various State departments of mines and from the files of the Federal Bureau of Mines. The records of coal-mine explosions are not complete for the early years of coal mining in the United States, therefore a number of explosions may not be included; however, since 1910 the Bureau of Mines has data on virtually every explosion entailing loss of life or considerable property damage.

The first available information on an explosion in a bituminous-coal mine in the United States concerned one in Virginia in 1839, and the first recorded explosion in Pennsylvania anthracite occurred in 1847. Table 1 gives data on 2,866 explosions that resulted in 13,880 deaths from 1839 to June 30, 1937, inclusive.

5/ Cash, F. E., and Humphrey, H. B., Explosions in Alabama Coal Mines: Inf. Circ. 6352, Bureau of Mines, 1930, 8 pp.
Kintz, G. M., and Denny, E. H., Explosions in Colorado Coal Mines: Inf. Circ. 6753, Bureau of Mines, 1933, 20 pp.
Herbert, C. A., Explosions in Illinois Coal Mines: Inf. Circ. 6764, Bureau of Mines, 1934, 13 pp.
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Davies, J. F., and Humphrey, H. B., Explosions in Kentucky Coal Mines: Inf. Circ. 6754, Bureau of Mines, 1934, 21 pp.
Kintz, G. M., Explosions in New Mexico Coal Mines: Inf. Circ. 6760, Bureau of Mines, 1934, 10 pp.
Forbes, J. J., and Humphrey, H. B., Explosions in Pennsylvania Coal Mines: Inf. Circ. 6710, Bureau of Mines, 1933, 28 pp.
Humphrey, H. B., Explosions in Tennessee Coal Mines: Inf. Circ. 6424, Bureau of Mines, 1931, 6 pp.
Parker, D. J., Explosions in Utah Coal Mines: Inf. Circ. 6752, Bureau of Mines, 1933, 15 pp.
Davies, J. F., and Humphrey, H. B., Explosions in Virginia Coal Mines: Inf. Circ. 6766, Bureau of Mines, 1934, 25 pp.
Ash, S. H., Explosions in Washington Coal Mines: Tech. Paper 507, Bureau of Mines, 1931, 52 pp.
Forbes, J. J., and Owings, C. W., Coal-Mine Explosions in West Virginia: Inf. Circ. 6802, Bureau of Mines, 1934, 51 pp.
Kintz, G. M., Wyoming Coal Mine Explosions: Inf. Circ. 6765, Bureau of Mines, 1934, 20 pp.

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TABLE 1. - Summary of mine explosions by States1/

I. C. 7001

State	Record period	Fatalities by ignition causes: Electricity Deaths	Electricity Explosions	Open lights or smoking Deaths	Open lights or smoking Explosions	Explosives Deaths	Explosives Explosions	Miscellaneous, unknown or no record Deaths	Miscellaneous, unknown or no record Explosions	Total Deaths	Total Explosions	Major explosions 2/ No.	Major explosions 2/ Percent	Average deaths per explosion
Alabama	1893-1937	124	5	557	100	313	20	24	5	1,018	130	32	24.6	7.8
Arkansas	1897-1937	-	-	16	2	25	8	-	-	41	10	2	20.0	4.1
Colorado	1883-1937	106	8	460	43	162	20	82	3	810	74	25	33.7	10.9
Illinois	1883-1937	20	5	371	30	246	131	127	78	764	244	25	10.2	3.1
Indiana	1878-1937	-	-	226	69	171	113	53	52	450	234	10	4.2	1.9
Iowa	1892-1937	-	-	-	-	55	15	8	1	63	16	3	19.0	3.9
Kansas	1885-1937	7	3	53	24	171	86	2	1	233	114	3	2.6	2.0
Kentucky	1884-1937	19	2	182	27	145	31	3	2	349	62	22	35.5	5.6
Maryland	1916-1937	-	-	17	2	-	-	-	-	17	2	1	50.0	8.5
Missouri	1888-1937	2	1	19	7	14	6	-	-	35	14	2	14.3	2.5
New Mexico	1895-1937	153	5	10	1	285	6	30	3	478	15	9	60.0	31.9
North Carolina	1895-1937	2	1	49	5	53	1	-	-	104	7	2	28.6	14.9
Ohio	1874-1937	84	3	79	32	11	3	8	3	182	41	5	12.2	4.4
Oklahoma	1885-1937	103	5	331	80	292	80	19	3	745	168	12	7.1	4.4
Pennsylvania bituminous	1878-1937	527	29	859	41	505	17	119	89	2,010	176	52	29.5	11.4
Pennsylvania anthracite	1847-1937	20	5	392	90	61	16	1,779	1,132	2,252	1,243	54	4.3	1.8
Tennessee	1891-1937	-	-	318	14	89	13	6	6	413	33	8	24.2	12.5
Utah	1900-1937	33	5	175	3	200	1	-	-	408	9	5	55.5	45.3
Virginia	1839-1937	3	2	271	21	258	7	34	3	566	33	22	66.6	17.1
Washington	1892-1937	39	8	113	24	99	13	47	2	298	47	12	25.5	6.3
West Virginia	1887-1937	712	42	830	59	514	30	54	32	2,110	163	62	38.0	12.9
Wyoming	1881-1937	43	3	101	4	178	3	212	21	534	31	10	32.2	17.2
Total		1,997	132	5,429	678	3,847	620	2,607	1,436	13,880	2,866	378	13.2	4.8
Average deaths per explosion		15.1		7.7		6.2		1.8		4.8				

1/ In which 1 or more men were killed. 2/ In which 5 or more men were killed.

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The States with the greatest number of deaths from explosions are Pennsylvania (anthracite), 2,252; West Virginia, 2,110; Pennsylvania (bituminous), 2,010; Alabama, 1,018; and Colorado, 801.

West Virginia leads all States, with the greatest number of major explosions, while Pennsylvania anthracite and Pennsylvania bituminous are next in order. Utah has the dubious honor of having the greatest percentage of major explosions, and undoubtedly the main reason for this is the extreme explosibility of Utah coal dust. Only a small percentage of the explosions in Indiana and Kansas have been of the major type, as most of them have occurred during shot-firing when only the shot-firers were underground. The percentage of major explosions in Pennsylvania anthracite also is low, due probably to the fact that anthracite dust is not explosive, or at least is relatively inexplosive, and most of the gas explosions have been confined largely to the region adjacent to the point of ignition. The average number of deaths per explosion in Pennsylvania anthracite was 1.8, while Utah has averaged 45.3 deaths and New Mexico 31.9 deaths per explosion; these latter two States have had comparatively few explosions, but most of those that have occurred have been widespread and have resulted in large loss of life.

Ignition of gas or dust by electricity has caused 132 explosions that have resulted in 1,997 deaths. West Virginia had the greatest number of explosions of electrical origin (42), with 712 deaths, and Pennsylvania bituminous had 29 electrical ignitions, with 527 deaths. Arkansas, Indiana, Iowa, Kansas, Maryland, and Tennessee have had no explosions ascribed to electricity up to the date of writing this circular.

Ignition of gas by open lights has caused 678 explosions and 5,429 deaths. Alabama has had the greatest number of explosions started by open lights - 100, with 557 deaths; Pennsylvania anthracite, 90, with 392 deaths; Indiana, 69 with 226 deaths; West Virginia, 59 with 830 deaths; and the other coal-mining States combined have had fewer than 50 explosions caused by open lights or smoking.

Explosions originating from blasting numbered 620, with 3,847 deaths, more deaths than from any other cause except open lights and smoking. Illinois has had the greatest number of explosions from explosives - 131, with 246 deaths; Indiana is next with 113 explosions and 171 deaths; Kansas has had 86 explosions; Kentucky, 31 explosions; Oklahoma, 80; West Virginia, 30; and Alabama and Colorado, 20 each. The other States have had fewer than 20 explosions caused by blasting.

A total of 1,436 explosions are listed as due to miscellaneous or unknown causes or to causes not shown by the records. About 78 percent of the explosions thus classified occurred in Pennsylvania anthracite mines, record of the causes of a large number of which could not be found. These occurred in the early days of mining before detailed records were kept; however, most of these explosions probably were caused by open lights, by blasting, or by misuse of flame safety lamps.

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Table 1 shows that explosions caused by electricity averaged the greatest number of deaths per explosion (15.1); explosions caused by open lights averaged 7.7 deaths per explosion; explosions due to explosives, 6.2 deaths per explosion; and miscellaneous or unknown causes, 1.8 deaths per explosion. The 2,866 explosions averaged 4.8 deaths per explosion.

COMPARISON OF EXPLOSION CAUSES BY STATES

Table 2 compares causes of explosions by States. Open lights or smoking has been the greatest single cause of explosions, having been responsible for 23.7 percent of all explosions. Many of the explosions caused by open lights occurred before the advent of electric-battery cap lamps, and the frequent occurrence of explosions from this cause provided an incentive to development of that lamp.

Twelve of the explosions under this heading were charged to defective flame safety lamps (most of them Davy lamps in anthracite mines) or to unsafe use of these lamps. Ten explosions were caused when firebosses and officials attempted to relight flame safety lamps with matches in the presence of gas; at least three of these were widespread and resulted in large loss of life. It is very probable that many of the explosions assessed against miscellaneous causes actually were precipitated by misuse of flame safety lamps.

Alabama has had the greatest number of explosions caused by open lights or smoking, 76.9 percent of a total of 130 explosions having been due to this cause. Pennsylvania anthracite mines have experienced 90 explosions (7.3 percent of the total for anthracite mines) of gas ignited by open lights or smoking. Only two explosions have been recorded in Maryland - both caused by open lights. In Ohio, 78.1 percent of the explosions were recorded as having been caused by open lights. Indiana, West Virginia, Colorado, and Pennsylvania bituminous mines also have had a large number of explosions caused by open lights or smoking.

Second in importance as a cause of explosions are explosives, 21.6 percent of the explosions having been caused by them, as shown in table 2. In Kansas, Illinois, Iowa, Kentucky, and Arkansas, 50 percent or more of the explosions that have been recorded were charged to explosives. Many of them were so-called "shot-firer" explosions and occurred before permissible explosives came into general use. For many years in some of our Midwestern States most of the coal was blasted from the solid with black powder and fuse or squibs, the blasting being done by shot-firers after all other men were out of the mine. This practice resulted in many explosions that killed one or two men at a time. In at least one district this type of explosion became so prevalent that the State mine inspector required the shot-firer at each mine to telephone his office after he had completed shooting. If no word was received from a shot firer in a reasonable time, it was assumed that an explosion had occurred and a rescue crew was sent to investigate.

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TABLE 2. - Comparison of explosions by ignition causes, by States

State	Electricity		Open lights or smoking		Explosives		Miscellaneous, or unknown cause		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Alabama	5	3.8	100	76.9	20	15.4	5	3.8	130	100
Arkansas	-	-	2	20.0	8	80.0	-	-	10	100
Colorado	8	10.8	43	58.1	20	27.0	3	4.1	74	100
Illinois	5	2.0	30	12.3	131	53.8	78	31.9	244	100
Indiana	-	-	69	29.5	113	48.3	52	22.2	234	100
Iowa	-	-	-	-	15	93.8	1	6.2	16	100
Kansas	3	2.6	24	21.1	86	75.5	1	.8	114	100
Kentucky	2	3.2	27	43.6	31	50.0	2	3.2	62	100
Maryland	-	-	2	100.0	-	-	-	-	2	100
Missouri	1	7.1	7	50.0	6	42.9	-	-	14	100
New Mexico	5	33.3	1	6.7	6	40.0	3	20.0	15	100
North Carolina	1	14.3	5	71.4	1	14.3	-	-	7	100
Ohio	3	7.3	32	78.1	3	7.3	3	7.3	41	100
Oklahoma	5	3.0	80	47.6	80	47.6	3	1.8	168	100
Pennsylvania bituminous	29	16.5	41	23.3	17	9.6	89	50.6	176	100
Pennsylvania anthracite	5	.4	90	7.3	16	1.3	1,132	91.0	1,243	100
Tennessee	-	-	14	42.4	13	39.4	6	18.2	33	100
Utah	5	55.6	3	33.3	1	11.1	-	-	9	100
Virginia	2	6.1	21	63.7	7	21.2	3	9.0	33	100
Washington	8	17.0	24	51.0	13	27.7	2	4.3	47	100
West Virginia	42	25.8	59	36.2	30	18.4	32	19.6	163	100
Wyoming	3	9.7	4	12.9	3	9.7	21	67.7	31	100
Total	132	4.6	678	23.7	620	21.6	1,436	50.1	2,366	100

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Of the 620 explosions reported to have been caused by explosives, 403 were reported to have been caused by "blown-out" shots; Kansas had 86, Oklahoma 80, and West Virginia 76 of these so-called "blown-out"-shot explosions. This type of explosion has almost disappeared, as the mining laws of most States do not now permit "shooting off the solid." The more general use of permissible explosives and improved blasting practices are also factors in the reduction of explosions from "blown out" shots. Insofar as now known, no explosion has been caused by permissible explosives when used in a permissible manner.

Numerous disastrous explosions have been caused by "bull-dozing" shots; that is, in breaking rock or boulders the charge of explosives is placed in contact with the rock and is not confined in a hole. "Bull-dozing" shots raise coal dust in suspension and ignite it, causing an explosion, the flame from this explosive being totally unconfined, hence able to do maximum harm in igniting coal dust or any gas that may be present.

The use of granular black powder has decreased considerably during the past 15 or 20 years; however, during the past few years black blasting powder has been marketed in pellet or stick form, and though many mining men believe that black powder in pellet or stick form is much safer than in granular form, this impression is definitely erroneous. About the only safety advantage of pellet or stick black powder over granular powder is that the former is easier to handle and is less likely to be ignited by open flame.

Electricity has been held responsible for 132 (4.6 percent) of the explosions. The first explosion of record caused by an electric arc occurred in West Virginia in 1901. The first electrical explosions in other States, according to available records, occurred as follows: Washington, 1909; Colorado, 1910; Pennsylvania bituminous, 1911; Alabama, 1916; Illinois, 1917; Pennsylvania anthracite, 1920; New Mexico, 1922; Utah and Wyoming, 1924; Kentucky, 1927; and Virginia, 1928. For the past several years the number of explosions caused by explosives and open lights has been declining rapidly, while the number of explosions caused by electric arcs have increased; this is due largely to the introduction of closed lights and permissible explosives and to the more general use of electricity underground.

Explosions from miscellaneous or unknown causes numbered 1,436 (50.1 percent of the total). Many such explosions occurred before the general use of electricity underground, and probably could be charged to open lights, smoking, or blasting, and probably to some extent to the misuse of the flame safety lamp. Pennsylvania anthracite had 1,132 explosions of this kind, and 67.7 percent of the explosions in Wyoming also were thus classified. One reason for the large number of such explosions is that in many instances reports did not state the cause of the explosions, many of which probably were caused by open lights or blasting.

COMPARISON OF EXPLOSION FATALITIES BY IGNITION CAUSES

Table 3 compares explosion fatalities by causes and shows that open lights and smoking have caused explosions that resulted in the greatest loss of life. Pennsylvania and West Virginia have suffered the greatest loss of life from open-light explosions, while more than 50 percent of the explosions in Alabama, Colorado, Indiana, Kentucky, Maryland, Missouri, and Tennessee that have caused lives to be lost have been of open-light origin, according to the record.

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TABLE 3. - Comparison of explosion fatalities, by ignition causes

State	Electricity		Open lights or smoking		Explosives		Miscellaneous or unknown cause		Total	
	Deaths	Percent	Deaths	Percent	Deaths	Percent	Deaths	Percent	Deaths	Percent
Alabama	124	12.2	557	54.7	313	30.7	24	2.4	1,018	100
Arkansas	-	-	16	39.0	25	61.0	-	-	41	100
Colorado	106	13.1	460	56.8	162	20.0	82	10.1	810	100
Illinois	20	2.6	371	48.6	246	32.2	127	16.6	764	100
Indiana	-	-	226	50.2	171	38.0	53	11.8	450	100
Iowa	-	-	-	-	55	87.3	8	12.7	63	100
Kansas	7	3.0	53	22.7	171	73.4	2	.9	233	100
Kentucky	19	5.4	182	52.2	145	41.5	3	.9	349	100
Maryland	-	-	17	100.0	-	-	-	-	17	100
Missouri	2	5.7	19	54.3	14	40.0	-	-	35	100
New Mexico	153	32.0	10	2.1	285	59.6	30	6.3	478	100
North Carolina	2	1.9	49	47.1	53	51.0	-	-	104	100
Ohio	84	46.2	79	43.4	11	6.1	8	4.3	182	100
Oklahoma	103	13.8	331	44.4	292	39.2	19	2.6	745	100
Pennsylvania bituminous	527	26.2	859	42.8	505	25.1	119	5.9	2,010	100
Pennsylvania anthracite	20	.9	392	17.3	61	2.7	1,779	79.1	2,252	100
Tennessee	-	-	318	77.0	89	21.5	6	1.5	413	100
Utah	33	8.0	175	43.0	200	49.0	-	-	408	100
Virginia	3	.5	271	47.9	258	45.6	34	6.0	566	100
Washington	39	13.1	113	37.9	99	33.2	47	15.8	298	100
West Virginia	712	37.8	830	39.3	514	24.4	54	2.5	2,110	100
Wyoming	43	8.1	101	18.9	178	33.3	212	39.7	534	100
Total	1,997	14.4	5,429	39.1	3,847	27.7	2,607	18.8	13,880	100

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Open lights and smoking have been the ignition cause in 39.1 percent of the fatalities from explosions, as listed in these records; however, during the past 7 years fatalities from explosions from this cause have been reduced to about 23 percent.

Explosions resulting from blasting are responsible for the next greatest number (about 27.7 percent) of explosion fatalities, Pennsylvania bituminous and West Virginia have suffered the greatest loss of life from explosions initiated by explosives, while more than 50 percent of the explosion fatalities in Arkansas, Kansas, Iowa, New Mexico, and North Carolina were caused by explosives. The severity of such explosions is indicated by the following: Utah, 1 explosion with 200 fatalities; New Mexico, 6 explosions with an average of 47 fatalities per explosion; Pennsylvania bituminous, with an average of 29 fatalities per explosion; West Virginia, with an average of 17 fatalities; and Kansas and Oklahoma, with the greatest number of explosions from this cause, averaged 2 and 3.6 fatalities per explosion, respectively, the explosions usually involving only the shot-firer.

Table 3 shows that explosives were responsible for 16 explosions that caused only 2.7 percent of the total explosion fatalities in Pennsylvania anthracite mines. Although many anthracite mines are gassy, the low fatality rate from explosions caused by explosives probably is due to the fact that anthracite dust is not explosive, or at least that its explosibility is limited.

About 19 percent of the explosion fatalities of record were due to miscellaneous or unknown causes. In Pennsylvania anthracite, 79.1 percent of the fatalities from explosions are listed under this heading; as stated before, many of these fatalities probably were from other causes. In Wyoming, 39.7 percent of the fatalities are attributed to miscellaneous or unknown causes.

Electricity as a cause of explosions was responsible for 14.4 percent of all fatalities from explosions of record, most of which have occurred since 1910. West Virginia heads the list in number of deaths (712) from electrical explosions, and Pennsylvania bituminous is second with 527 fatalities. Explosions of electrical origin have accounted for more than 100 deaths in Alabama, Colorado, New Mexico, and Oklahoma. It can be noted from table 3 that Iowa, Indiana, Maryland, Missouri, and Tennessee have not recorded an explosion caused by electricity.

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ELECTRICAL CAUSES OF EXPLOSIONS

Table 4 gives the electrical causes of explosions, by States. Nonpermissible mining machines and trolley or cable-reel locomotives have been the greatest source of explosions started by electricity. Possibly all of the explosions caused by nonpermissible mining machines could have been avoided if ventilation had been effective or if proper tests for gas had been made before the machines were moved into the working places, or if permissible mining machines had been used. Explosions caused by trolley or cable-reel locomotives could have been prevented by the use of storage-battery locomotives for gathering; keeping these dangerous open-type locomotives in strictly fresh intake air at all times would have prevented many of these explosions. West Virginia has had the greatest number of explosions of electrical origin (42), with Pennsylvania bituminous next with 29. Washington has had 8 explosions started by electricity; Colorado 8; Alabama, Illinois, New Mexico, Oklahoma, and Utah, 5 each; Kansas and Wyoming, 3 each and Kentucky and Virginia, 2 each.

SUMMARY

Mining men of experience realize that the coal-mining industry has been fortunate in its explosion experience; the factors that contribute to an explosion are ever present in virtually all coal mines, and only a combination of circumstances is required to bring about an explosion. All of these factors, however, are subject to control, and this has been amply provided, as evidenced by the good records of 1933, 1934, 1935, and 1936, when only 12 major explosions with 101 deaths occurred in the coal mines of the United States. The factor contributing most to explosions is inadequate or interrupted ventilation. Inadequate ventilation at working faces in many mines is due to clogged airways and leaky stoppings. Ventilation interrupted by open doors has been responsible for many explosions; this could be remedied by replacing doors with overcasts or by installing automatic doors or doors in pairs. The human factor must always be considered in connection with the prevention of explosions, and it can be controlled only by adequate supervision and proper safety education.

Numerous mines in the United States have been rock-dusted with the idea of preventing propagation of an explosion; however, only a small percentage of the supposedly rock-dusted mines contain sufficient rock dust to insure any considerable degree of protection should an explosion be initiated. Many coal-mine operators seem to believe that one application of rock dust will render a mine immune from spreading of explosions during the remainder of its life. Other operators apply rock dust to the main haulage entries and hope that if an explosion occurs it will not travel the air courses. Such methods are not only false economy, but the operator who indulges in such practices is likely to receive a rude awakening. Many mines have been worked out without suffering an explosion, but this has been due more to the grace of God than to any precautionary measures taken by mining people.

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TABLE 4. - Electrical causes of explosions by States

State	Number of explosions, by cause												
	Trolley or cable-reel locomotive	Nonpermissible mining machine	Nonpermissible electric motor	Nonpermissible shot-firing battery	Cable nips or cable blow-out	Nonpermissible electric drill	Nonpermissible storage-battery locomotive	Nonpermissible electric hoist	Faulty mining	Trolley wire	Electric arc	Signal wire	Total explosions
Alabama	-	-	-	-	-	-	-	1	-	-	4	-	5
Arkansas	-	-	-	-	-	-	-	-	-	-	-	-	0
Colorado	1	2	-	-	1	-	-	1	1	1	1	-	8
Illinois	3	1	-	-	-	-	-	-	-	1	-	-	5
Indiana	-	-	-	-	-	-	-	-	-	-	-	-	0
Iowa	-	-	-	-	-	-	-	-	-	-	-	-	0
Kansas	-	-	1	-	-	-	-	-	1	-	1	-	3
Kentucky	-	1	1	-	-	-	-	-	-	-	-	-	2
Maryland	-	-	-	-	-	-	-	-	-	-	-	-	0
Missouri	-	-	-	-	-	-	-	-	-	-	1	-	1
New Mexico	-	1	1	-	-	-	-	-	-	1	1	1	5
North Carolina	-	-	-	-	-	-	-	-	-	-	1	-	1
Ohio	-	-	-	-	-	-	-	-	-	-	3	-	3
Oklahoma	-	1	-	1	1	-	-	-	2	-	-	-	5
Pennsylvania bituminous	4	5	5	-	5	-	1	1	5	1	2	-	29
Pennsylvania anthracite	2	-	1	-	-	-	-	-	-	-	2	-	5
Tennessee	-	-	-	-	-	-	-	-	-	-	-	-	0
Utah	1	4	-	-	-	-	-	-	-	-	-	-	5
Virginia	-	-	1	-	-	-	-	-	-	-	1	-	2
Washington	2	-	2	-	-	-	1	-	-	-	3	-	8
West Virginia	15	14	-	-	4	1	3	-	1	2	2	-	42
Wyoming	-	1	-	-	-	1	-	-	-	1	-	-	3
Total	28	30	12	1	11	2	5	3	10	7	22	1	132

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Frequency and severity of mine explosions in the United States have shown an encouraging downward trend during the past 6 years. From 1906 to 1910, inclusive, an average of 478 men were killed annually by coal-mine explosions in the United States. During the following 20-year period (1911 to 1930, inclusive) the average annual death rate from explosions was reduced to 303; and during the past 6 years (1931 to 1936, inclusive) the average annual toll of lives by explosions was 74. The best year in the history of mining was 1933, when only 40 deaths resulted from explosions; the next best year was 1936, with 45 deaths from explosions. The frequency of occurrence of explosions has not been reduced in the same ratio as the severity; however, the severity of major explosions (in which 5 or more men are killed) has been reduced materially. During the 4-year period 1907 to 1910, inclusive, there were 67 major coal mine disasters, resulting in a total of 2,249 fatalities; during the 4-year period 1933 to 1936, inclusive, there were only 12 major coal mine disasters with a total of 101 fatalities. Comparing these two periods, the frequency of occurrence of major coal-mine disasters has been reduced about 82 percent and the severity more than 95 percent. The material decline in the frequency and severity of explosions during the past 6 years is believed to have been due primarily to (1) increased vigilance of the various State mine inspection departments, especially in educational work, and demands for more rigid adherence to State laws and to safety practices far beyond the strict letter of the law; (2) the growing realization of the economic waste of accidents, including explosions, and more or less general acceptance by the mine operators of responsibility for accident occurrence; and (3) the widespread dissemination of safety data by the Bureau of Mines and other safety organizations.

COST OF EXPLOSIONS

Cost of explosions includes (1) compensation, (2) medical and hospital fees, (3) property damage due to violence of the explosion, and (4) loss of production, which might include loss of bonuses, payment of forfeits, cancellation of orders, loss of customer good will, etc. Other losses of both a direct and an indirect nature might be mentioned but the above are those of greatest importance.

It would be difficult to calculate the compensation loss incurred in connection with the 13,880 deaths caused by explosions in the United States. Compensation payments for industrial accidental deaths vary in different States; a large percentage of the 13,880 deaths from explosions occurred long before compensation laws were enacted. However, many of the explosions that have occurred in the coal mines of the United States have cost more than $1,000,000 even before compensation payments were as heavy as at present.

To arrive at a figure that will show approximately the compensation cost of the 13,880 deaths from explosions, it is necessary to make two assumptions: First, the application of present-day compensation cost to all of these deaths and, second, that 50 percent of those killed left dependents. As the greatest number killed by explosions were in Alabama, Pennsylvania, and West Virginia, the average maximum compensation benefits of these three States will be used as a basis for calculating the compensation cost.

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1. Average maximum compensation benefits in these States for those having dependents = $6,333.

2. Average maximum compensation benefits for those having no dependents = $133.

3. Average burial benefit = $118.

Based on these figures, the total compensation cost for the 13,880 deaths from explosions would be:

6,333 x 6,940 =	$43,951,020
133 x 6,940 =	923,020
118 x 13,830 =	1,637,840
	46,511,880

The above does not take into account the compensation cost of those injured by explosions, which would add many millions to the cost.

Cost of property damage by explosions varies with each explosion. One explosion might kill a number of men on a section and do virtually no damage outside that section. On the other hand, a shot-firer explosion may kill only one or two men but totally wreck the mine (in some instances the tipple and surface buildings have been wrecked). Property damage caused by explosions has been so great at several mines that no attempt has been made to reopen the mines and they have been abandoned. The average compensation cost of 13 major explosions in Pennsylvania during 1916-1929 was $121,117.6/ Compensation cost of explosions is usually a minor part of the total cost, as often damage to property, cost of recovery, and loss of business amount to many times the compensation cost. Numerous coal-mine explosions have occurred in the United States with little or no loss of life but with property loss totaling several hundred thousand dollars.

It is fairly generally accepted that the indirect cost of accidents is four times the direct cost, but it is believed that when explosion accidents alone are considered the ratio is much greater. Even using the 4 to 1 ratio, the cost of $232,559,400 for the 13,880 deaths from explosions in the United States is appalling. It is not claimed that this figure is accurate, but at least it gives an approximation of the cost of explosions.

Some of the salient facts brought out in the study of mine explosions in the United States during the period 1839 to 1937 are:

1. The first bituminous-coal-mine explosion of record occurred on March 18, 1839, at the Black Heath Mine near Richmond, Va., and resulted in 40 deaths. The first recorded anthracite-mine explosion occurred on February 19, 1847, and resulted in 7 deaths. Both of these explosions were ascribed to open lights.

6/ Fene, W. J., Accident Experience and Costs in Pennsylvania Anthracite and Bituminous Mines, 1926-1930: Inf. Circ. 6618, Bureau of Mines, 1932, 29 pp.

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2. The first explosion of record caused by an electric arc occurred in West Virginia in 1901.

3. The frequency and severity of explosions have been reduced from an average annual death toll of 438 during the period 1906 to 1910 to an average of 32 deaths during the period 1933 to 1936.

4. Since 1839 there have been in the United States 2,866 explosions of which records are available, in which one or more men were killed, with a total of 13,880 deaths.

5. The States having the greatest number of deaths from explosions are Pennsylvania (anthracite), 2,252; West Virginia, 2,110; Pennsylvania (bituminous), 2,010; Alabama, 1,018; and Colorado, 810.

6. West Virginia leads all States with the greatest number of major explosions (62), followed by Pennsylvania anthracite with 54 and Pennsylvani bituminous with 52, a major explosion being one in which 5 or more lives are lost.

7. Electricity has caused 132 (4.6 percent) of the explosions and 1,997 (14.4 percent) of the deaths. West Virginia has had 42 explosions ascribed to electricity as the igniting cause, with 712 deaths, and Pennsylvania bituminous has had 29 such explosions with 527 deaths.

8. Explosions of electrical origin were the severest of the four types of explosions classified, and averaged 15.1 deaths per explosion; those due to open lights or smoking averaged 7.7 deaths per explosion; and those ascribed to explosives averaged 6.2 deaths per explosion. The average for the 2,866 recorded explosions was 4.8 deaths per explosion.

9. Ignition of gas by open lights or smoking is recorded as having been the cause of 678 explosions and 5,429 deaths.

10. Explosions originating from explosives numbered 620, with 3,847 deaths.

11. Miscellaneous or unknown causes are recorded as having caused 1,436 explosions with 2,607 deaths.

12. Open lights and smoking have been the greatest single cause of explosions (23.7 percent of all explosions) and deaths from explosions (39.1 percent of all deaths from explosions).

13. Explosives were responsible for the second greatest number of explosions (21.6 percent) and deaths from explosions (27.7 percent).

14. Of the 620 explosions caused by explosives, 403 are reported to have been due to "blown-out" shots.

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15. Explosions attributed to miscellaneous or unknown causes represent 50.1 percent of the total number. Many of the explosions under this classification probably were caused by open lights, blasting, or misuse of the flame safety lamp.

16. Of the electrical equipment responsible for explosions, nonpermissible mining machines and trolley or cable-reel locomotives lead.

17. Twelve explosions were reported as having been caused by defective flame safety lamps, and 10 by attempts of firebosses and officials to relight flame safety lamps with matches in the presence of gas.

CONCLUSIONS

The remedies for the prevention of coal-mine explosions are now too well known to warrant repeating here. In the early days of mining, however, precautionary measures to prevent explosions were not so well known and there may have been some excuse for an operator when an explosion occurred; but in this age, with definite knowledge both as to cause and prevention, explosions certainly are inexcusable.

The coal-mining industry has been relatively free from disastrous mine explosions during the past 8 years, compared with previous periods; and although there are those in the industry who still trust in fate to protect them, the industry as a whole is to be commended not only for its efforts to prevent mine explosions but also for the degree of success that has rewarded those efforts. Nevertheless, the trend of occurrence of coal-mine explosions and of fatalities from them seems to be upwards since the all-time "low" of 1933, and it would be well for our mining men to realize that while mine disasters can be prevented, this prevention cannot be achieved without a concerted continued effort towards that end.

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